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Introduction of an electrolytic topping up bath to dye-sensitized photo electrochemical solar cells

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ABSTRACT

Photocurrent, photovoltage and efficiency of dye sensitized PEC cells have been extensively investigated with I^-/I_3^- redox couple. Gradual degradation of both the dye and the semiconductor material take place in these cells due to change of chemical composition of those materials in prolong illumination. But evaporation of electrolyte due leakage, which arise due to excess pressure build by thermal expansion of the electrolyte is a more serious problem. This was investigated in this study and an alternative solution is presented to over come this problem. Our attempt was to make a durable PEC cell with higher efficiency. This task was achieved by introducing an electrolytic topping up bath to the PEC cell.

1. INTRODUTION

Dye-sensitized nanocrystalline TiO_2 solar cells offer an alternative to low cost thin film solar cells. These solar cells consists of a dye adsorbed porous nanocrystalline TiO_2 matrix deposited on conducting tin oxide glass (CTO) interpenetrated by I_3^-/I^- redox electrolyte.

Photovoltaic effect of dye deposited semiconductor thin films and their utilization in photo electrochemical (PEC) solar cells have been extensively investigated in the past decades [1-5]. The mechanism of charge injection to the semiconductor and transport of charge carriers[2] in nanocrystalline thin films are fairly well understood. A dye sensitized photo electrochemical solar cells based on nanocrystalline films of TiO_2 with a practical viable conversion efficiency of solar energy to electricity exceeding 10% is an important contribution made by Gratzel and Co-workers[1] in this context. It has also been reported that the photovoltaic conversion efficiency of the dye sensitized PEC cells could be further improved by coating an ultra thin insulating barrier layer on the nanocrystalline semiconductor particles on which the dye is adsorbed.

The fascinating phenomenon of dye-sensitization also mimics the photosynthesis where a dye molecules attached to a semiconductor injects charge carriers to the bands of the semiconductor upon photo excitation. These cells are based on high band gap semiconductor materials, which resist the photo corrosion in electrolytic media. Apart from the photo stability of high band gap semiconductor materials, they could possibly be polycrystalline materials with low purity because dye-sensitization process involves only a single band where both electrons and holes are not accommodated in the same semiconductor material. Thus bulk recombination arising from impurities and defects are nonexistent in dye-sensitized solar cells.

Despite the above attractive features there are some drawbacks in PEC cells. Mainly they are degradation of the dye and the semiconductor that arise due to change of chemical composition and evaporation of electrolytic media due to leakage that occurs due to excess pressure build in the electrolyte due to thermal expansion. In this investigation problem related to leakage of electrolyte is addressed and effort was made to overcome it by introducing an electrolytic topping up bath to the PECs by the means of drilling a small hole on the counter electrode to connect with an electrolytic reservoir on the rear side of the cell. With this device the excess pressure built up in the PEC reduces by motion of electrolyte through the hole to the topping up bath.

2. EXPERIMENTAL

To prepare the TiO_2 films on CTO glass, 1 g of Degussa (p-25) powder was weighted. 2 ml of acetic acid was added to this powder in an agate mortar. Then it was ground well and 2 ml of ethanol was added while grinding further. This paste was used to coat a film on the CTO glass using the doctor blade method. The films were sintered at 550 °C in a furnace for 30 minutes. The dye was coated by immersing the film in a solution of Ruthenium bipyridyle dye dissolved in ethanol for 12 hours. The photoelectrochemical solar cell was made by placing the dye coated TiO_2 plate on CTO glass and filling the capillaries of the mesoporous film with an electrolyte containing I_3^-/I^- redox couple in acetonitrile. The electrolytic topping up bath was formed by sticking a glass slide on the counter electrode where three glass strips stick to it at the three edges such that to make a space between the counter electrode and the glass slide.

The cell was illuminated with a 1.5 AM, 1000 Wm^{-2} solar simulator lamp. I-V characteristics of the cells were recorded using a Keithley 2420-3A source meter.

3. RESULTS AND DISCUSSION

Typical picture of a dye sensitized PEC cell is given below in figure 1. In this structure electrolyte that penetrate into the pours of the film is sealed in between the CTO glass with the TiO_2 film and the Pt coated counter electrode.

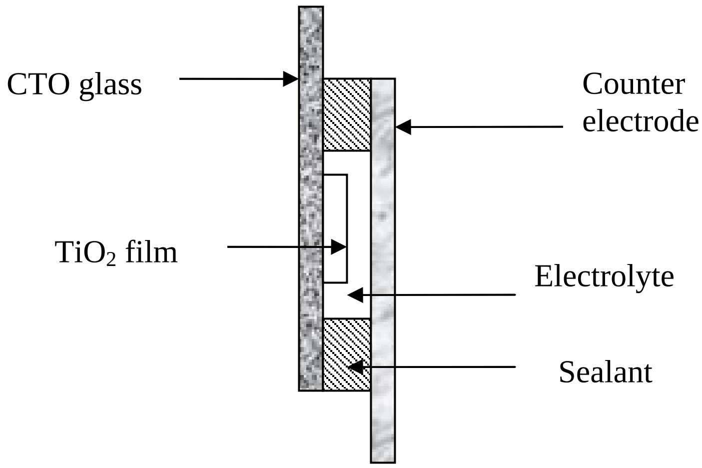

Figure 1 : Typical PEC Cell

-Complete sealing of the electrolyte can be seen in a typical PEC cell of this nature as in the above figure. But we have observed some drawbacks in that cell. Due to thermal expansion of electrolyte, sealing material would be damaged by the excess pressure build inside the cell. Because of this the electrolyte that leak out tends to evaporate gradually with time. To balance the pressure inside the cell with outside, we have formed an electrolytic topping up bath attached to a typical PEC cell that is given in the following figure.

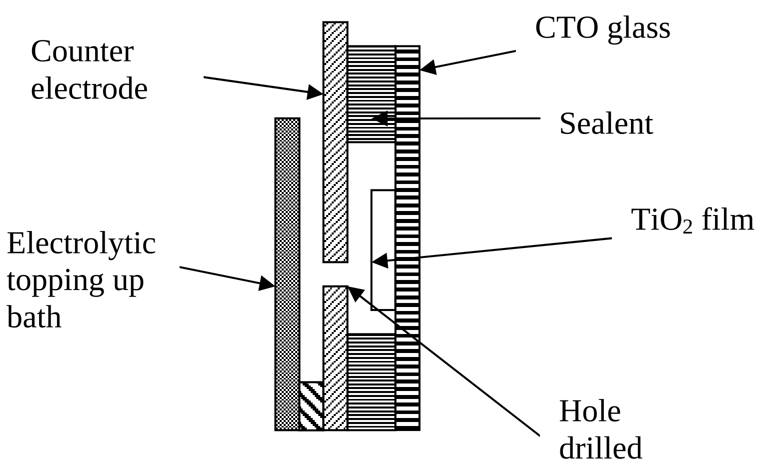

Figure 2: PEC cell with electrolytic topping up bath

Then electrolytic topping up bath was filled with the electrolyte. The PEC cell was irradiated with a CFL bulb for seven consecutive days and photo current and photo voltage were measured during that period.

During the first few days photo current and photo voltage remain unchanged but after that photo voltage started to dropped by small values. This is supposed to the degradation of both the dye and the semiconductor material. Due to prolong illumination of the cell shallow traps formed in the band gap of TiO_2 (TiO_2 is a high band gap semiconductor about 3.1 eV) which would decreases the photovoltage of the cell up to a certain level. Because of these trap states germinated electrons will recombine with holes in the electrolytic media which will also reduces the photocurrent. Therefore photocurrent and photo voltage will be dropped by a certain value after several weeks. But even after the monitoring period the electrolyte remain without leakage. Major advantage of this method is ability to tolerate the excess pressure build up inside the cell. Experiments are also conducted to rule out the formation of shallow traps in the semiconductor material that will help to make the dye-sensitized solar cells viable devices.

4. CONCLUSIONS

Efficiency of typical PEC cell reduces gradually with time. One of the reasons is evaporation of the liquid electrolyte. Change of chemical composition of both the dye and the electrolyte also affect the performance of the cell. To address the first effect, an electrolytic topping up bath was introduced to the PECs which showed great achievement in their performances.

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